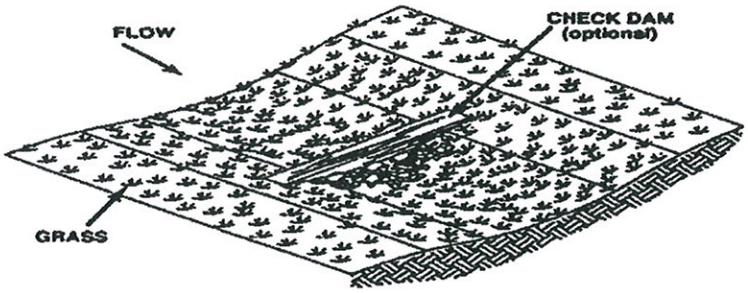
ACTIVITY: Biofilters: Swales and Strips	**WPTP-03**



Targeted Constituents

● Significant Benefit ◗ Partial Benefit ○ Low or Unknown Benefit

● Sediment	● Heavy Metals	◗ Floatable Materials	◗ Oxygen Demanding Substances
◗ Nutrients	● Toxic Materials	● Oil & Grease	○ Bacteria & Viruses	○ Construction Wastes

Implementation Requirements

● High ◗ Medium ○ Low

◗ Capital Costs	◗ O & M Costs	◗ Maintenance	○ Training

Description

There are two types of biofilters: swales and filter strips. A swale is a vegetated channel that treats concentrated flow. A filter strip treats sheet flow and is placed parallel to the contributing surface. This management practice is likely to provide a significant reduction in sediment, heavy metals, toxic materials, oil and grease and partial reductions in nutrients, floatable materials, and oxygen demanding substances.

Selection Criteria

- Biofilters are often used in conjunction with other stormwater management practices.
- Biofilters are often placed along or serve parking lots. See Figure WPTP-03-2 for an illustration of how swales draining to slightly raised inlets can be used as pretreatment.
- Performance somewhat less than wet ponds and constructed wetlands.
- Limited to treating a few acres.
- Minimizing DCIA involves ensuring that as much runoff as possible from impervious areas is routed over relatively large pervious areas and, in some cases, choosing an alternative surface to pavement or concrete that allows for some degree of infiltration. Figure WPTP-03-3 is an illustration of an example parcel that has been modified to convert a portion of the DCIA into non-directly connected impervious area by rerouting the roof gutters over the lawn (properly graded between houses) and to convert a portion of the DCIA to pervious area by using a porous surface.
- Landscaped swales can be used around parking lots, houses, and other structures. The swales will provide pretreatment and also provide conveyance to larger secondary or primary stormwater management systems.
- Connections from the curbs to roadside swales can be provided to route street flow

to grass-lined swales before discharge to the secondary or primary stormwater management system. Since roadway runoff may contain a greater pollutant load than runoff from most other surfaces, providing swale pretreatment of roadway runoff will reduce pollutant loads to the regional ponds and improve the overall efficiency of the BMP treatment train. The swale space required for pretreatment of roadway runoff in roadside swales can be incorporated into green space requirements and be used to enhance the aesthetics of the roadways.

Design and Sizing Considerations

- These systems should be designed by a licensed professional civil engineer.
- A biofilter swale is a vegetated channel that looks similar to, but is wider than, a ditch that is sized only to transport flow. The biofilter swale must be wider to maintain low flow velocities and to keep the depth of the water below the height of the vegetation up to a particular design event. A filter strip is placed along the edge of the pavement (its full length if possible). The pavement grade must be such as to achieve sheet flow to the maximum extent practical along the strip.
- The type of filter strip discussed here is not to be confused with the natural vegetated buffer strip used in residential developments to separate the housing from a stream.
- Properly designed swales are useful for proper grading around houses as well as detention / retention prior to discharge into a secondary or primary system. Fill from the shallow swale area may be used elsewhere on the property to improve the grading plan. Landscaped swales would typically be 0.5 to 1.0 foot (0.15 to 0.3 m) deep and should have side slopes no steeper than 4:1 (H:V), with side slopes of 6:1 (H:V) or greater being less noticeable and more attractive.
- Grass-lined swales may be constructed around parking lots and commercial centers as recessed planters for landscaping. The swales could be part of the landscaping and would incorporate raised inlets (4 to 6 inches (10.2 to 15.2 cm)) into the design, which will allow for the initial 0.25 inch (0.64 cm) retention volume for pretreatment. Although groundwater tables in the developable area are generally within 1 to 2 feet (0.3 to 0.61 m) of the surface, recovery times for retention volumes of approximately 0.25 inches (0.64 cm) should be sufficiently small to allow the use of limited retention. Minimum infiltration rates of 0.1 inch (0.25 cm) / hour are expected, allowing a relatively quick drawdown. Swales incorporated within commercial areas can enhance aesthetics and be used as credit towards green space and landscaping requirements. Figure WPTP-03-2 shows an example of a landscaped swale with a raised inlet. These landscaped swales use runoff to water plants and improve aesthetics.
- The connections between the curb and the swale can be implemented in two ways. The first method is to provide regularly spaced flumes in the curb as the connection to the swale. This method would be less expensive and will be aesthetically appealing (Figure WPTP-03-4). Another way is to provide a 4- to 6-inch (10.2 to 15.2 cm) diameter pipe approximately every 200 feet (61 m) between the curb and the swale. This method may provide better erosion control at the edge of the curb by preventing flowing water over the interface of the curb and the swale. The disadvantage to this method is the potential for clogging, and

thus the requirement for increased maintenance, in these small pipes.

- The problem of spreading the flow across the width of the swale may limit its use to tributary catchments of only a few acres.

- The length of pavement prior to the filter strip should not exceed a few hundred feet to avoid channelization of large aggregates of runoff along the pavement before it reaches the pavement edge. To avoid channelization, care must be taken during construction to make sure that the cross-section of the biofilter is level and that its longitudinal slope is even. Channelization will reduce the effective area of the biofilter used for treatment and may erode the grass because of excessive velocities.

- The design engineer must determine the width of a swale using Manning's Equation and the 2-year rainfall intensity appropriate to the site. An n value of 0.20 to 0.24 is recommended depending on the expected height of the turf (dependent upon mowing frequency). The design engineer must also calculate the peak flow of the 100-year event to determine the depth of a swale to convey flood flows. Since a width using an "n" of 0.20 is generally wider than what is required of a grass lined channel, channel stability should not be of concern. It is generally not necessary to have a bypass for the extreme events because the minimum width specification limits erosive velocities if there is a relatively gentle slope. If erosion at extreme events is of concern, consider the above concepts to minimize erosion.

- The design engineer can make the swale wider than determined in the above step, with a corresponding shortening of the swale length to obtain the same surface area. However, there is a practical limitation on how wide the swale can be and still be able to spread the flow across the swale width.

- Splitting the flow into multiple inlets and/or placing a flow spreader near the storm inlet should be incorporated into the design. A concept that may work is to place a level 2" x 12" (5.1 cm x 30.5 cm) timber or equivalent concrete, aluminum or gravel structure across the width of the swale 8-15 feet (2.4-4.6 m) from the pipe outlet. Place gravel between the outlet and the timber, to within 2 inches (5.1 cm) or so of the top of the timber. Place large rock immediately near the outlet to dissipate the flow energy: the rock also may help distribute the flow.

- Residence time for "maximized" captured runoff should be at least 5 minutes. Use a runoff coefficient of C=1.0 assuming complete runoff and no infiltration.

- The maximum velocity should be no more than 0.9 ft/sec (0.3 m/s).

- Maximum bottom width of 8 ft (2.4 m) unless level spreaders are installed frequently (every 50 feet (15.2 m)).

- Average depth of flow should be no more than 1.0 in. (25 mm), and maximum depth should be no more than 3 in. (75 mm) for grass or approximately 2 in. (50 mm) below the height of the shortest wetland plant species in the biofilter. Furthermore, the maximum flow depth should be no greater than one-third of the gross or emergent wetland vegetation height for infrequently moved swales or greater than one-half of the vegetation height for regularly mowed swales.

- The minimum width for a swale is determined by Manning's Equation.
- Minimum length of a swale is 100 feet (30.5 m) unless level spreaders are used at least every 50 feet (15.2 m) or as necessary to prevent flow channelizations.
- Minimum length of a filter strip is 10 feet (3 m).
- Maximum length without a level spreader is 80 feet (24.4 m) for a filter strip or swale.
- The longitudinal slope must not exceed 5%.
- Use a flow spreader and energy dissipator at the entrance of a swale.
- Good soils are important to achieve good vegetation cover.
- WEF Manual of Practice No. 23 / ASCE Manual and Report on Engineering Practice No. 87 (1998) should be consulted for additional guidance on the design, construction, and maintenance of biofilters.
- Achieve sheet flow with filter strips.

Construction/ Inspection Considerations

The swale bottom must be as level as possible; energy dissipation and a flow spreader should be placed at the entrance to minimize channelization. The pavement must be as level as possible along its boundary with a biofilter strip. The pavement edge should be left clear; that is, no curbs or an inflow level spreader should be placed at each curb cut. Parking stall blocks must be open to pass the flow as unhindered as possible. Use of curb cuts in curbs without additional inflow level spreaders is not a satisfactory approach. The cuts channelize the water and can clog with debris. The performance of filter strips may be compromised by the failure to achieve sheet flow at the interface between the paved area and the strip.

Turf grass is the preferred vegetation. Turf grass may require summer irrigation to remain active. The soil must be of a fertility and porosity that allows for healthy vegetation. A porous soil also promotes infiltration.

If erosion of the swale is of concern because of the difficulty of maintaining a good grass cover, consider the use of modular concrete grids or similar material. Another concept is to use check dams and level spreaders to divide the swale into a series of terraces, reducing the longitudinal slope to perhaps 1%, thereby reducing flow velocities.

Maintenance

- The facility should be checked annually for signs of erosion, vegetation loss, and channelization of the flow.

- The grass should be mowed when it reaches a height of 8 inches (20.3 cm). Allowing the grass to grow taller may cause it to thin and become less effective. The clippings should be bagged and removed.

- Keep all level spreaders even (level) and free of debris.

- Mow grass covered biofilters regularly to promote growth and pollutant uptake. Remove cuttings and dispose of properly (preferably through composting).

- Remove sediment by hand with a flat-bottomed shovel during dry periods.

- Remove only the amount of sediment necessary to restore hydraulic capacity, leaving as much of the vegetation in place as possible. Reseed or plug any damaged turf or vegetation.

- Eventually, sufficient sediment will be trapped that the entire biofilter will need to be removed with sediment and reconstructed to begin a new cycle of stormwater quality control.

Sediment Removal

- A primary function of biofilters, swales, and strips is to collect sediments. The sediment accumulation rate is dependant on a number of factors including watershed size, facility sizing, construction upstream, industrial or commercial activities upstream, etc. The sediment contents should be identified before it is removed and disposed.

  Some sediment may contain contaminants of which the Tennessee Department of Environment and Conservation (TDEC) requires special disposal procedures. If there is any uncertainty about what the sediment contains or it is known to contain contaminants, then TDEC should be consulted and their disposal recommendations followed. The TDEC – Division of Water Pollution Control should be contacted at (615) 532-0625. Generally, special attention or sampling should be given to sediments accumulated in facilities serving industrial, manufacturing or heavy commercial sites, fueling centers or automotive maintenance areas, large parking areas, or other areas where pollutants (other than "clean" soil) are suspected to accumulate and be conveyed via storm runoff.

  Some sediment collected may be innocuous (free of pollutants other than "clean" soil) and can be used as fill material, cover or land spreading. It is important that this material not be placed in a way that will promote or allow resuspension in storm runoff. The sediment should not be placed within the high water level area of the pond, other BMP, creek, waterway, buffer, runoff conveyance device, or other infrastructure. Some demolition or sanitary landfill operators will allow the sediment to be disposed at their facility for use as cover. This generally requires that the sediment be tested to ensure that it is innocuous.

- The grass should be mowed no shorter than 3 inches (7.6 cm).

Limitations

- Poor performance occurs when the swale or filter strip is undersized, or when runoff is allowed to channelize in the swale or filter strip.

- Cannot be placed on steep slopes.
- Proper maintenance required to maintain health and density of vegetation.

Additional Information

The performance of biofilters is probably somewhat less than wet ponds and constructed wetlands because the latter provide treatment both during and between storms. Some researchers have observed poor performance, recommending their use only in combination with other treatment control BMPs. However, most field research on swale performance has been conducted on grassed roadside swales. A swale must be wider than a traditional roadside ditch, to avoid excessive flow velocities which topple the grass and cause channelization.

A biofilter is sized to treat all storms up to a particular design event. The design event can be relatively small because the aggregate of all small events represents the majority of pollutant runoff. Research in western Washington (Metro, 1992) found that a biofilter sized according to this technique removed 80% of the suspended solids and attached pollutants and 50% of the soluble zinc. It was not able to remove dissolved phosphorus or copper.

A minimum length of 10 feet (3 m) is recommended for biofilter strips (100 feet (30.5 m) for swales). Length here is defined as the measurement in the direction of flow from the adjoining pavement. Lengths of 20 to 50 feet (6.1 to 15.2 m) have been recommended by most practitioners perhaps because of the concern that sheet flow cannot be maintained. Wherever space permits, a length greater than 10 feet (3 m) should be used.

Primary References

California Storm Water Best Management Practice Handbooks, Municipal and Industrial Handbooks, CDM et.al. for the California SWQTF, 1993.

Caltrans Storm Water Quality Handbooks, Construction Contractor's Guide and Specifications, April 1997.

Camp Dresser & McKee, *Sevenmile Creek Basin Pilot Stormwater Quality Master Plan*, Report to Metropolitan Nashville and Davidson County, Tennessee, December 1999.

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Roesner, L. A., Aldrich, J., Hartigan, J.P., et.al., *Urban Runoff Quality Management – WEF Manual of Practice No. 23 / ASCE Manual and Report on Engineering Practice No. 87*, 1998.

Subordinate References

California Cooperative Agricultural Extension (CCAE), 1984, *"Selecting the Best Turf Grass"*, Leaflet 2589.

CCAE, 1985, *"Turfgrass Water Conservation"*, Bulletin 21405.

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Federal Highway Administration (FHWA), 1989, *"Retention, Detention, and Overland Flow for Pollutant Removal of Highway Stormwater Runoff* (Draft)", Report No. FHWA/RD-89/203.

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Metropolitan Washington Council of Governments (MWCOG), March, 1992, *"A Current Assessment of Urban Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone"*.

Municipality of Metropolitan Seattle, (Metro), 1992, *"Pollutant Removal Effectiveness of a Designed Grassy Swale in Mountlake Terrace, Washington* (Draft)".

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Tollner, E.W., and B.J. Barfield, 1976, *"Suspended Sediment Filtration Capacity of Simulated Vegetation"*, Trans. American Society of Agricultural Engineers, 19, 678.

Youngner, V.B., J.H. Madison, M.H. Kimball, and W.B. Davis, 1962, *"Climatic Zones for Turfgrass in California"*, California Agriculture, 16 (7), 2.

COLD TOLERANCE (winter color persistance)

High
- Creeping bentgrass
- Kentucky bluegrass
- Red fescue
- Colonial bentgrass
- Highland bentgrass
- Perennial ryegrass
- Tall fescue
- Weeping alkaligrass
- Dichondra
- Zoysiagrass
- Common bermudagrass
- Hybrid bermudagrass
- Kikuyugrass
- Seashore paspalum
- St. Augustinegrass

Low

HEAT TOLERANCE

High
- Zoysiagrass
- Hybrid bermudagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Dichondra
- Creeping bentgrass
- Kentucky bluegrass
- Highland bentgrass
- Perennial ryegrass
- Colonial bentgrass
- Weeping alkaligrass
- Red fescue

Low

MOWING HEIGHT ADAPTATION

High cut
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Weeping alkaligrass
- St. Augustinegrass
- Common bermudagrass
- Dichondra
- Kikuyugrass
- Colonial bentgrass
- Highland bentgrass
- Zoysiagrass
- Seashore paspalum
- Hybrid bermudagrass
- Creeping bentgrass

Low Cut

DROUGHT TOLERANCE

High
- Hybrid bermudagrass
- Zoysiagrass
- Common bermudagrass
- Seashore paspalum
- St. Augustinegrass
- Kikuyugrass
- Tall fescue
- Red fescue
- Kentucky bluegrass
- Perennial ryegrass
- Highland bentgrass
- Creeping bentgrass
- Colonial bentgrass
- Weeping alkaligrass
- Dichondra

Low

MAINTENANCE COST AND EFFORT

High
- Creeping bentgrass
- Dichondra
- Hybrid bermudagrass
- Kentucky bluegrass
- Colonial bentgrass
- Seashore paspalum
- Perennial ryegrass
- St. Augustinegrass
- Highland bentgrass
- Zoysiagrass
- Tall fescue
- Common bermudagrass
- Kikuyugrass

Low

Note: Consult *Landscaping with Native Plants – Middle Tennessee Central Basin and Highland Rim*, Tennessee Exotic Pest Plant Council, May 1998.

FIGURE WPTP-03-1
TURF GRASS SPECIES

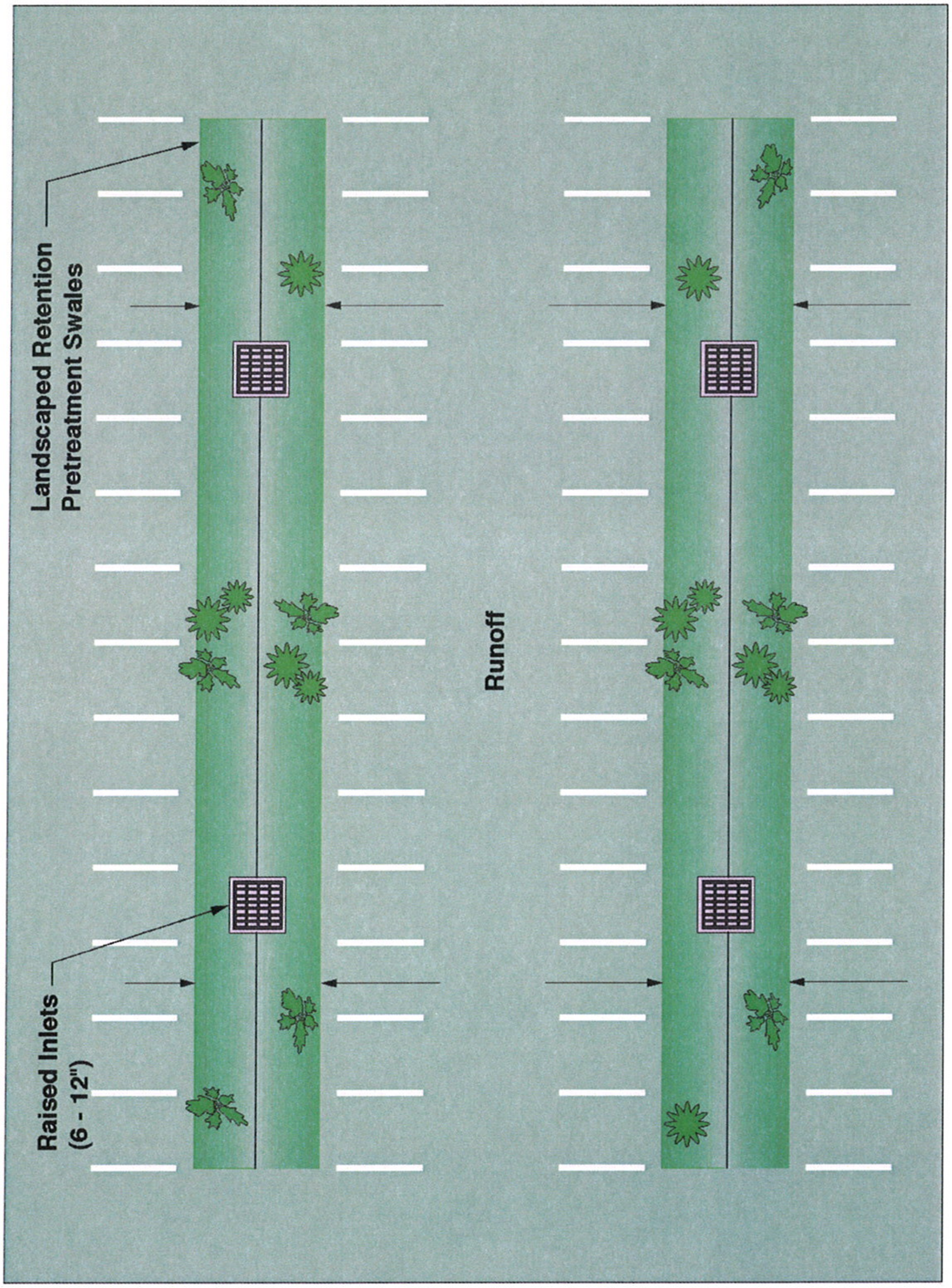

Figure WPTP-03-2
Landscaped Retention Pretreatment Swales
With Raised Inlets

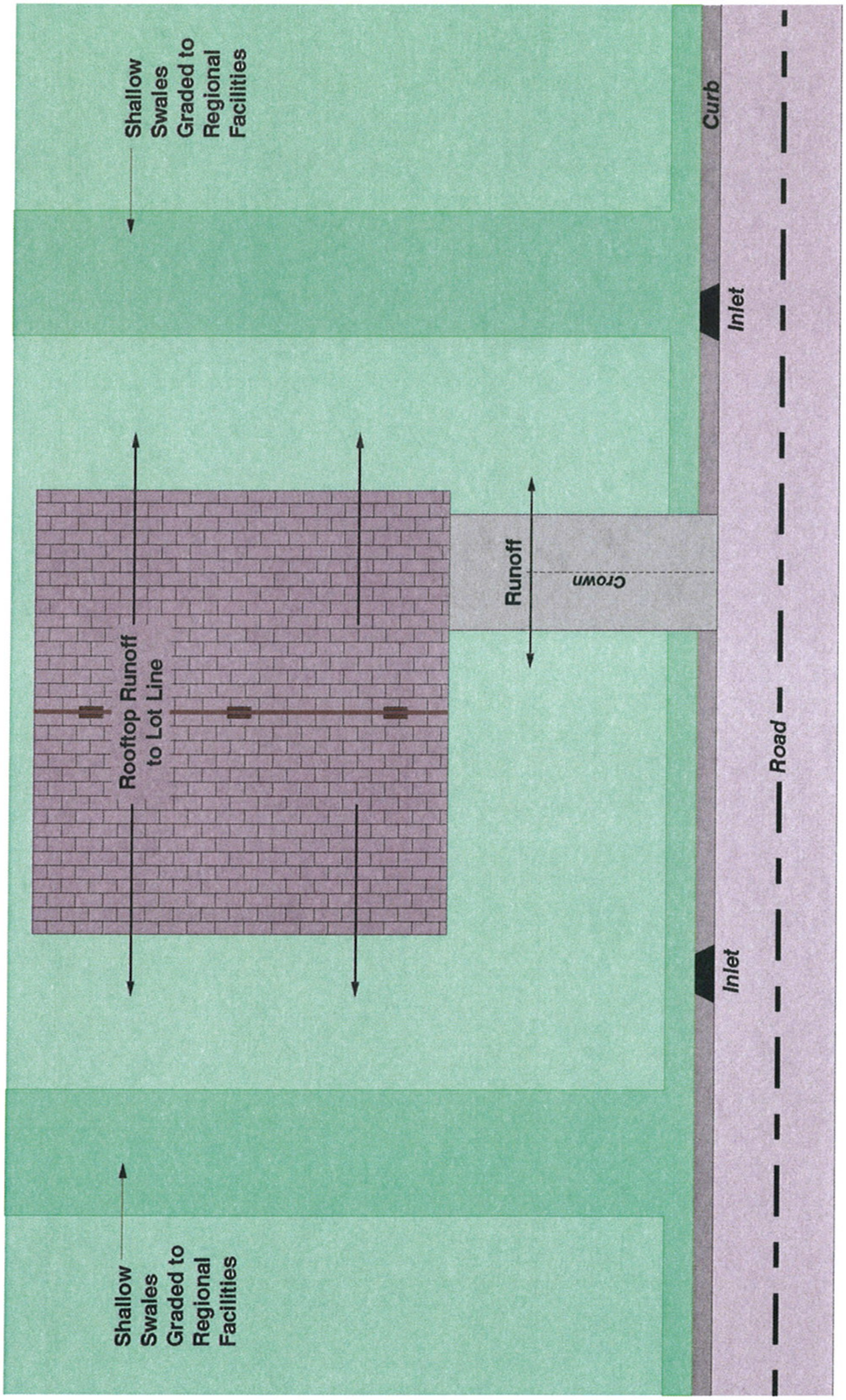

Figure WPTP-03-3
Minimization of DCIA and Use of Grass Lined Swales

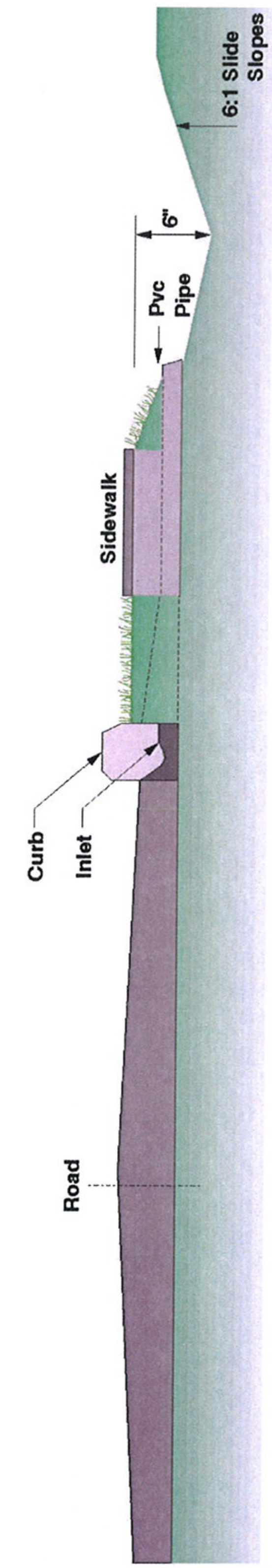

Figure WPTP-03-4
Roadside Swales